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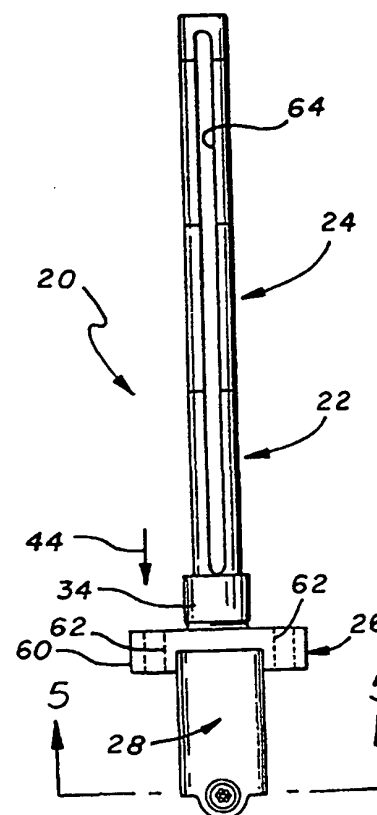
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(54) Title: CAPACITIVE SENSOR ASSEMBLY WITH SOOT BUILD-UP INHIBITING COATING

(57) Abstract

A sensor assembly (20) for measuring characteristics of motor oil in a vehicle includes a housing (22) adapted to be mechanically coupled to a vehicle for receiving motor oil of the vehicle and at least one capacitive sensor (68, 70, 72) including sensing electrodes (74, 76) positioned relative to the housing (22) to measure characteristics of motor oil between the sensing electrodes (74, 76). The sensing electrodes (74, 76) are coated with a soot build-up inhibiting coating (204, 206) which, in a preferred embodiment, is a silicone coating. The at least one capacitive sensor (68, 70, 72) includes an oil level sensor (68) and an oil deterioration sensor (72) in a preferred embodiment.



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CAPACITIVE SENSOR ASSEMBLY
WITH SOOT BUILD-UP INHIBITING COATING

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. patent application serial number 08/767,808, filed December 17, 1996, entitled CAPACITIVE SENSOR ASSEMBLY, by Kyong M. Park, Nhan
5 Nguyen and Marcos A. Nassar.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a sensor assembly for
10 measuring characteristics of motor oil in a vehicle and, more particularly, pertains to a capacitive sensor with electrodes coated with a silicone coating to inhibit build-up of soot or carbon on the electrodes.

15 Description of the Related Art

Today's luxury automobiles rely heavily upon control systems which receive input signals from a wide variety of sensing devices. To ensure proper functioning of these control systems, a large number of highly dependable and accurate
20 electronic transducers are needed to provide the aforementioned input signals. A problem with capacitive sensors employed to provide such input signals is the build-up of soot or carbon on the electrodes of the capacitive sensors. Thus, there is a need for a capacitive sensor with electrodes coated with a
25 coating that inhibits the build-up of soot or carbon on the electrodes.

SUMMARY OF THE INVENTION

In accordance with a specific illustrative embodiment of
30 the present invention, a sensor assembly for measuring

characteristics of motor oil in a vehicle includes: a housing mechanically coupled to a vehicle in a substantially fixed orientation relative to the vehicle, the housing including a chamber for receiving motor oil of the vehicle, the chamber
5 being formed and positioned relative to other components of the vehicle such that a volume of the motor oil proportionally related to a total volume of motor oil in the vehicle is provided to the chamber; and a plurality of capacitive sensors positioned within the housing, each of the capacitive sensors
10 including a plurality of sensing electrodes, the capacitive sensors being adapted to measure a plurality of characteristics of the motor oil between the sensing electrodes, each of the sensing electrodes being covered by a silicone coating.

In a further aspect of the present invention, the
15 plurality of capacitive sensors include an oil level sensor and an oil deterioration sensor.

In a further aspect of the present invention, the sensor assembly further includes a tilt sensor mechanically coupled to the housing in a substantially fixed orientation relative to
20 the vehicle, the tilt sensor provides an output signal indicative of an orientation of the tilt sensor relative to a vector representing forces applied to the tilt sensor.

In another aspect of the present invention, a sensor assembly for measuring characteristics of motor oil in a
25 vehicle includes: a housing mechanically coupled to a vehicle in a substantially fixed orientation relative to the vehicle, the housing being formed and positioned relative to other components of the vehicle to receive a volume of motor oil proportionally related to a total volume of motor oil in the
30 vehicle; and at least one capacitive sensor mechanically coupled to the housing, the at least one capacitive sensor including a plurality of sensing electrodes, the at least one

capacitive sensor being adapted to measure at least one characteristic of motor oil between at least two of the sensing electrodes, each of the sensing electrodes being covered by a silicone coating.

5 In another aspect of the present invention, a sensor assembly for measuring characteristics of motor oil in a vehicle includes: a housing adapted to the mechanically coupled to a vehicle; and at least one capacitive sensor mechanically coupled to the housing, the at least one capacitive sensor
10 including a plurality of sensing electrodes, the at least one capacitive sensor being adapted to measure at least one characteristic of motor oil between at least two of the sensing electrodes, each of the sensing electrodes being covered by a non-conductive coating.

15

DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the invention will become readily apparent upon reference to the following detailed description when considered in conjunction with the
20 accompanying drawings, in which like reference numerals designate like parts throughout the figures thereof, and wherein:

FIG. 1 is a cross-sectional perspective view of an exemplary preferred multifunctional sensor assembly according
25 to the present invention; the view additionally includes an exploded view of a tilt sensor assembly of the multifunctional sensor assembly;

FIG. 2 is a side view of the multifunctional sensor assembly of FIG. 1;

30 FIG. 3 is a cross-sectional front view of the multifunctional sensor assembly of FIG. 1;

FIG. 4 is a partial cross-sectional rear view of the multifunctional sensor assembly of FIG. 1;

FIG. 5 is a cross-sectional end view of the multifunctional sensor assembly along lines 5-5 of FIG. 2;

5 FIG. 6 shows perspective views of an electrode substrate and a ground plate of the tilt sensor assembly of FIG. 1;

FIG. 7 is a front view of the electrode substrate of the tilt sensor assembly of FIG. 1;

10 FIGS. 8A, 8B and 8C are front views of the electrode substrate and a top surface of fluid within the tilt sensor assembly of FIG. 1; the electrode substrate being shown in FIGS. 8A, 8B and 8C, respectively, at a maximum negative tilt angle, a nominal tilt angle and a maximum positive tilt angle;

15 FIG. 9 shows plots of output voltages generated by output electronics of the tilt sensor assembly of FIG. 1 as a function of tilt angle at -30°C, room temperature and 85°C;

FIG. 10 is an alternative preferred embodiment of the sensor assembly which includes the tilt sensor assembly of FIG. 1 and tilt sensor output signal conditioning electronics; and

20 FIG. 11 is an alternative preferred embodiment of the multifunctional sensor assembly of FIG. 1, the alternative embodiment being of reduced overall length and including a repositioned oil deterioration sensor assembly of alternative design.

25

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIG. 1, an exemplary multifunctional sensor assembly 20 includes a housing 22 which, in turn, includes an upper housing portion 24, an intermediate housing portion 26 and a lower housing portion 28. The sensor assembly 20 also includes an electrode support structure 30; and the upper housing portion further includes a sleeve portion 32.

In the illustrated preferred embodiment, the intermediate housing portion 26 includes a collar portion 34 with a substantially cylindrical inner surface 36. The electrode support structure 30 preferably includes a lower portion 38 with a substantially cylindrical outer surface 40. The sleeve portion 32 is preferably cylindrical in shape and sized to receive the electrode support structure 30 into the upper housing portion 24 with the outer surface 40 fitting snugly against the inside surface of the sleeve portion 32. In similar fashion, the inner surface 36 of the collar portion 34 is complementary to the outer surface of the sleeve portion 32 and sized such that the sleeve portion 32 fits snugly within the intermediate housing portion 26 when the sensor assembly 20 is fully assembled.

The multifunctional sensor assembly 20 measures characteristics of motor oil in a vehicle (e.g., oil level, oil temperature and oil deterioration) as well as an angular position of a tilt sensor assembly 42 relative to a vector 44 representing a vector sum of forces applied to the tilt sensor assembly 42. When the vehicle is not in motion, the aforementioned forces predominantly comprise gravity.

The tilt sensor assembly 42 includes an electrode substrate 46 upon which a thin conductive material is coated to form a measuring electrode 48 and a reference electrode 50. An exemplary electrode substrate 46 comprises a ceramic material.

The tilt sensor assembly 42 also includes a ground plate 52 and a gasket 54 which are shown in FIG. 1 in an exploded view.

The ground plate 52 is secured to the electrode substrate 46 at a predetermined distance from the electrodes 48, 50 (FIG. 5, also). The gasket 54 is fitted between the ground plate 52 and the electrode substrate 46 to provide a reservoir 56 within which a predetermined or controlled volume of a dielectric

fluid 58 is provided. An exemplary dielectric fluid 58 comprises a silicone fluid or other nonvolatile fluid which is of an appropriate viscosity to operate at high temperatures.

During assembly, the tilt sensor assembly 42 is
5 positioned within the lower housing portion 28. Thereafter, the intermediate housing portion 26 is welded to or secured to the lower housing portion 28 in some other conventional manner.

The electrode substrate 46 is constructed, the tilt sensor assembly 42 is positioned within the lower housing portion 28
10 and the volume of the dielectric fluid 58 is selected such that the reference electrode 50 is completely covered by the dielectric fluid 58, independent of the orientation of the tilt sensor assembly 42 relative to the vector 44. The complete immersion of the reference electrode 50, as stated above,
15 presupposes that the vehicle will be operated in a conventional fashion, e.g., with all of its wheels in contact with the driving surface.

The intermediate housing portion 26 further includes a flange portion 60, as best shown in FIG. 2. The flange portion
20 60 includes means for securing the sensor assembly 20 to a vehicle. Such securing means can, for example, comprise apertures 62 which are bored through the flange portion 60. As shown in FIG. 1, the sensor assembly 20 may also include a gasket 62 which is fitted around the collar portion 34 of the
25 intermediate housing portion 26. The gasket 62 serves to reduce vibrational contact between a mounting member of the vehicle (not shown) and the intermediate housing portion 26.

As shown in FIGs. 1 and 2, the upper housing portion 24 additionally includes flutes 64 which allow engine oil to enter
30 into the upper housing portion 24. The upper housing portion 24 is positioned relative to other components of the vehicle (not shown) to receive a volume of motor oil proportionally

related to a total volume of motor oil in the vehicle. The sensor assembly 20 also includes an end cap 66 which is sized to be fitted snugly within the upper housing portion 24. As the total volume of motor oil in the vehicle decreases, the
5 aforementioned volume of motor oil is forced by gravity toward the collar portion 34 and, as a result, enters into the upper housing portion 24 along progressively shorter portions of the flutes 64 beginning adjacent to the collar portion 34 and continuing toward the end cap 66. As best shown in FIG. 2, an
10 exemplary upper housing portion 24 includes two flutes 64 which are formed along substantially the entire length of the upper housing portion 24. However, the subject matter of the present invention additionally contemplates that the upper housing portion 24 may be formed with other types of openings or
15 apertures which facilitate the ingress of engine oil as discussed above.

Referring to FIG. 3, the illustrated exemplary embodiment of the sensor assembly 20 further includes an oil level sensor 68, a oil temperature sensor 70 and an oil deterioration sensor
20 72. Generally, a plurality electrodes are fitted about or otherwise supported within the upper housing portion 24 by the electrode support structure 30.

The oil level sensor 68 comprises an oil level measuring electrode 74 and an oil level reference electrode 76 which are
25 electrically isolated from each other by an insulator 78. The illustrated exemplary oil level measuring electrode 74 includes two portions: a rod portion 74a which is fitted at one end into the end cap 66 and a retaining portion 74b which is cylindrically bored as shown to receive the oil temperature
30 sensor 70, to fit snugly over the electrode support structure 30, and to receive the opposing end of the rod portion 74a. Thus, the end cap 66 and the retaining portion 74b secure the

rod portion 74a within the upper housing portion 24. The upper housing portion 24 serves as the ground terminal for both the oil level measuring electrode 74 and the oil level reference electrode 76. As the oil level decreases, the area of the measuring electrode 74 immersed in motor oil decreases resulting in a decrease in the capacitance between the measuring electrode 74 and the upper housing portion 24. As shown in FIG. 3, the electrode support structure 30 includes vias or conduits through which electrical connections from signal conditioning circuitry are made to the electrodes 74, 76. The capacitor formed between the measuring electrode 74 and the upper housing portion 24 varies in capacitance depending upon the volume of oil in the upper housing portion 24. The capacitor formed between the reference electrode 76 and the upper housing portion 24 does not vary in capacitance provided sufficient engine oil remains to completely immerse the reference electrode 76 at all times, even when the vehicle is moving.

A key aspect of the present invention is that the oil level measuring electrode 74 and the oil level reference electrode 76 are coated with a soot build-up inhibiting coating 204 and the upper housing portion 24 is coated with a soot build-up inhibiting coating 206. A build-up of soot or carbon on the sensor electrodes interferes with the free flow of oil over the electrodes. The coatings 204, 206 inhibit this build-up of soot or carbon thereby improving sensor performance.

In a preferred embodiment, the coatings 204, 206 comprise a silicone coating such as PHC587 Weatherable Abrasion-Resistant Primerless Silicone Hard Coat from GE Silicones at (800)255-8886. Prior to applying the coatings 204, 206, the surfaces to be coated should be clean, dust-free (Class 10,000 or better), well-ventilated and with a relative humidity of

approximately $40 \pm 10\%$. The surfaces to be coated are cleaned, for example, by washing or wiping with isopropyl alcohol, a mild detergent solution and clean water rinse, or ultrasonic bath followed by a filtered-air blowoff and a final ionized-air
5 blow off. The coating solution should be filtered continuously or just prior to use to approximately 0.5 to 1.0 micron, using a 3 to 5 micron prefilter. Conventional electric or indirect gas-fired ovens are employed to cure the coatings 204, 206 to a thickness of 6-8 microns at 130°C with primerless adhesion.

10 Alternatively, the coatings 204, 206 comprise a flowable, two-part, self-priming adhesive elastomer such as product number 96-083 by Dow Corning. A thinning agent, such as Dow Corning OS-10, is used to reduce the viscosity of the elastomer in order to obtain uniformity and thinner cured layers, and to
15 enable spray application. The ratio of elastomer to thinner is preferably 5 to 1. Although the coating can be applied by spraying, it can also be applied by brushing or dipping. The curing schedule for the elastomer is 150°C for 30 minutes minimum. It should be understood that the scope of the present
20 invention contemplates employing still other materials sufficiently slippery to inhibit build-up of soot or carbon on the sensor electrodes in place of the exemplary coatings set forth above. Such materials should inhibit soot build-up at least as well as Teflon®.

25 As best shown in FIG. 4, the exemplary sensor assembly 20 further includes an oil level sensor hybrid 78 which is electrically connected as discussed above to the capacitors formed by the electrodes 74, 76 and the upper housing portion 24. The oil level sensor hybrid 78 generates an output voltage
30 which is proportionally related to the ratio of the capacitance between the electrode 74 and the upper housing portion 24 to

the capacitance between the electrode 76 and the upper housing portion 24. Changes in this output voltage indicate changes in the oil level within the upper housing portion 24.

Referring to FIG. 3, an exemplary oil temperature sensor 5 70 comprises a Sensohm resistor available from the Ferro Corporation. The temperature variable resistive element is positioned sufficiently close to the oil level reference electrode 76 to remain thermally coupled to the motor oil within the upper housing portion 24, even when the oil level is 10 very low. As may be readily appreciated, the oil temperature sensor 70 can include alternative circuit elements whose electrical characteristics vary with changes in temperature.

The oil temperature sensor 70 generates an output voltage which is proportionally related to the temperature of the motor 15 oil within the upper housing portion 24. The electrode support structure 30 is preferably formed with an inner channel 80 through which electrical connections from the plurality of electrodes are routed.

The oil deterioration sensor 72 illustrated in FIG. 3 20 comprises an oil deterioration measuring electrode 82 and an oil deterioration reference electrode 84 which are electrically isolated from each other by an insulator 86. The oil level reference electrode 76 and the oil deterioration measuring electrode 82 are electrically isolated from each other by an 25 insulator 88. The upper housing portion 24 serves as a ground terminal for both the oil deterioration measuring electrode 82 and the oil deterioration reference electrode 84. The motor oil is a dielectric material and, because it circulates freely between the electrodes 82, 84 and the upper housing portion 24, 30 forms two capacitors; a first capacitor between the oil deterioration measuring electrode 82 and the upper housing portion 24 and second capacitor between the oil deterioration

reference electrode 84 and the upper housing portion 24. As the quality of the oil changes, e.g., deteriorates, the dielectric constant of the oil changes. The capacitor formed between the measuring electrode 82 and the upper housing portion 24 varies in capacitance depending upon the quality of the oil within the upper housing portion 24, as does the capacitor formed between the reference electrode 84 and the upper housing portion 24. As shown in FIG. 3, the electrode support structure 30 includes vias or conduits through which electrical connections from signal conditioning circuitry are made to the electrodes 82, 84.

As with the oil level sensor 68, the electrodes of the oil deterioration sensor 72 are also preferably coated with a soot build-up inhibiting coating such as PHC587 Weatherable Abrasion-Resistant Primerless Silicone Hard Coat from GE Silicones. More specifically, the oil deterioration measuring electrode 82 and the oil deterioration reference electrode 84 are coated with the soot build-up inhibiting coating 204 and the upper housing portion 24 is coated with the soot build-up inhibiting coating 206.

As shown in FIG. 4, the exemplary sensor assembly 20 further includes an oil deterioration sensor hybrid 90 which is electrically connected as discussed above to the capacitors formed by the electrodes 82, 84 and the upper housing portion 24. The oil deterioration sensor hybrid 90 generates an output voltage which is proportionally related to the capacitance between the oil deterioration measuring electrode 82 and the upper housing portion 24. Changes in this output voltage indicate changes in the quality of the motor oil within the upper housing portion 24. The oil deterioration sensor hybrid 90 utilizes the capacitance between the oil deterioration

reference electrode 84 and the upper housing portion 24 to compensate for oil temperature fluctuations.

The exemplary sensor assembly 20 also includes a tilt sensor hybrid 92 which is electrically connected to the capacitors formed by the electrodes 48, 50 and the upper housing portion 24. Operation of the tilt sensor hybrid 92 is discussed in greater detail with reference to FIGs. 6, 7, 8A-8C and 9.

The exemplary sensor assembly 20 shown in FIG. 4 also includes a circuit board 94 upon which the hybrids 78, 90, 92 are mounted. As may be readily appreciated, a plurality of hybrid circuits mounted on a common substrate is but one way in which signal conditioning can be realized. For example, the circuitry within the hybrids 78, 90, 92 could alternatively be condensed into a single integrated circuit package. The sensor assembly 20 additionally includes a conduit 96 and output leads 98. An exemplary conduit 96 is press fit or welded to the lower housing portion 28 as shown. The output leads 98 provide a means for delivering the conditioned output signals generated by the hybrids 78, 90, 92 and the oil temperature sensor 70 and, accordingly, are routed through the conduit 96.

FIG. 5 is a cross-sectional end view of the multifunctional sensor assembly 20 along lines 5-5 of FIG. 2 and best illustrates the mechanical interface between the electrode substrate 46, the ground plate 52 and the gasket 54, as well as the reservoir 56 formed thereby.

FIG. 6 shows perspective views of the electrode substrate 46 and the ground plate 52. In the illustrated preferred embodiment, the reservoir 56 is cylindrical in shape and a volume of the dielectric fluid 58 is selected such that one half of the reservoir 56 is filled with the dielectric fluid

58. A top surface 100 of the dielectric fluid 58 is shown along a diameter of the reservoir 56.

In FIG. 7, the tilt measuring electrode 48 and the tilt reference electrode 50 are shown in greater detail. As shown in FIGS. 8A-8C, the tilt sensor 42 is designed to operate within an anticipated angular range between $-\Theta$ and $+\Theta$. The reference electrode 50 is sized and positioned on the electrode substrate 46 such that it will always be immersed by the dielectric fluid 58, provided the tilt sensor assembly 20 is operating within the anticipated angular range. The measuring electrode 48 is sized and positioned on the electrode substrate 46 such that a submerged portion of the electrode 48, the ground plate 52 and the dielectric fluid 58 therebetween form a capacitor. Similarly, a capacitor is formed by the reference electrode 50, the ground plate 52 and the dielectric fluid 58 therebetween. The capacitances of the aforementioned capacitors are proportionally effected by changes in temperature. Accordingly, the latter capacitor is employed by the tilt sensor hybrid 92 to provide temperature compensation.

For purposes of the following equation, C_0 represents the capacitance between the tilt measuring electrode 48 and the ground plate 52 and C_r represents the capacitance between the tilt reference electrode 50 and the ground plate 52. The tilt sensor hybrid 92 generates an output voltage,

$$V_o \propto (C_0 - C_r) / (C_0 + C_r).$$

FIG. 8A shows the electrode substrate 46 at the maximum negative tilt angle $-\Theta$. To avoid electrical instability, the electrodes 48, 50 are preferably applied to the electrode substrate 46 such that the immersed portion of the tilt measuring electrode 48 is slightly larger than the total area of the tilt reference electrode 50 at the maximum negative tilt

angle $-\Theta$. FIG. 8B shows the electrode substrate 46 at a nominal tilt angle, such as when the vehicle is parked on a surface perpendicular to the vector 44. FIG. 8C shows the electrode substrate 46 at the maximum positive tilt angle $+\Theta$.

5 FIG. 9 shows plots of the output voltage V_0 generated by the tilt sensor hybrid 92 as a function of tilt angle at -30°C , 23°C (room temperature) and 85°C . The electronics within the tilt sensor hybrid 92 were trimmed to generate V_0 at 0.5 volts at a tilt angle of -45° , 2.5 volts at a tilt angle of 0° , and
10 4.5 volts at a tilt angle of $+45^\circ$. The following table sets forth the data point (in units of volts) plotted in FIG. 9.

TILT ANGLE (DEGREES)	-30°C	R.T.	85°C
-45	0.321	0.527	0.590
0	2.459	2.497	2.445
45	4.670	4.425	4.177

15 FIG. 10 shows an alternative sensor assembly 110 which includes a mounting bracket 112, a rear housing 114, an electrode substrate 116, a hybrid assembly 118, an assembly of feed-through capacitors and supporting plate 120, a front housing 122, an O-ring gasket 124, an assembly of output
20 terminals and flexible connecting strip 126 and a connector 128 assembled as shown. The electrode substrate 116 is substantially identical to the electrode substrate 46, but also includes a via 130 through which an electrical connection 132 is made between the hybrid assembly 118 and the rear housing
25 114 which serves as electrical ground. The hybrid assembly 118 is attached to one side of the electrode substrate 116 while

tilt measuring and reference electrodes (not shown) are positioned on the opposing side.

FIG. 11 illustrates an alternative multifunctional sensor assembly 140 which includes an oil deterioration sensor 142 positioned outside the upper housing portion 144 and directly exposed to a volume of motor oil 146. An exemplary oil deterioration sensor 142 comprises the oil deterioration sensor disclosed in U.S. Patent No. 5,540,086 to Park et al., the entirety of which is incorporated herein. The electrodes of the oil deterioration sensor 142 are coated with a coating such as PHC587 Weatherable Abrasion-Resistant Primerless Silicone Hard Coat from GE Silicones.

As shown in FIG. 11, an intermediate housing portion 148 is formed to receive the oil deterioration sensor 142 and the upper housing portion 144. The upper housing portion 144 is of a reduced overall length compared to the upper housing portion 24 because it does not include electrodes for an oil deterioration sensor. The remaining components of the sensor assembly 140 are substantially identical to their corresponding components in the sensor assembly 20 rendering a description of their structural and functional characteristics reiterative.

In conclusion, it is to be understood that the foregoing detailed description and the accompanying drawings illustrate the principles of the invention. However, various changes and modifications may be employed without departing from the spirit and scope of the invention. Thus, by way of example and not of limitation, the disclosed plurality of transducers could further include a pressure transducer or other sensing devices.

Accordingly, the present invention is not limited to the specific form shown in the drawings and described in detail hereinabove.

WHAT IS CLAIMED IS:

1. A sensor assembly for measuring characteristics of motor oil in a vehicle, the sensor assembly comprising:
 - a housing mechanically coupled to a vehicle in a substantially fixed orientation relative to the vehicle, said housing including a chamber for receiving motor oil of the vehicle, said chamber being formed and positioned relative to other components of the vehicle such that a volume of the motor oil proportionally related to a total volume of motor oil in the vehicle is provided to the chamber; and
 - a plurality of capacitive sensors positioned within said housing, each of said capacitive sensors including a plurality of sensing electrodes, said capacitive sensors being adapted to measure a plurality of characteristics of the motor oil between said sensing electrodes, each of said sensing electrodes being covered by a silicone coating.
2. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 1 wherein said plurality of capacitive sensors comprise an oil level sensor.
3. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 2 wherein said plurality of capacitive sensors further comprise an oil deterioration sensor.
4. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 2 wherein said oil level sensor and another of said plurality of capacitive sensors share a common electrode.

5. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 1 wherein said plurality of capacitive sensors comprise an oil deterioration sensor.

6. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 5 wherein said plurality of capacitive sensors further comprise an oil level sensor.

7. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 5 wherein said oil deterioration sensor and another of said plurality of capacitive sensors share a common electrode.

8. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 1 further comprising:

a tilt sensor mechanically coupled to said housing in a substantially fixed orientation relative to the vehicle, said
5 tilt sensor providing an output signal indicative of an orientation of said tilt sensor relative to a vector representing forces applied to said tilt sensor.

9. A sensor assembly for measuring characteristics of motor oil in a vehicle, the sensor assembly comprising:

a housing mechanically coupled to a vehicle in a substantially fixed orientation relative to the vehicle, said
5 housing being formed and positioned relative to other components of the vehicle to receive a volume of motor oil proportionally related to a total volume of motor oil in the vehicle; and

at least one capacitive sensor mechanically coupled to
10 said housing, said at least one capacitive sensor including a

plurality of sensing electrodes, said at least one capacitive sensor being adapted to measure at least one characteristic of motor oil between at least two of said sensing electrodes, each of said sensing electrodes being covered by a silicone coating.

10. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 9 wherein said at least one capacitive sensor comprises an oil level sensor.

11. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 10 wherein said at least one capacitive sensor further comprises an oil deterioration sensor.

12. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 9 wherein said at least one capacitive sensor comprises an oil deterioration sensor.

13. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 12 wherein said at least one capacitive sensor further comprises an oil level sensor.

14. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 9 further comprising:

5 a tilt sensor mechanically coupled to said housing, said tilt sensor providing an output signal indicative of an orientation of said tilt sensor relative to a vector representing forces applied to said tilt sensor.

15. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 14 wherein said tilt sensor is

coupled to said housing in a substantially fixed orientation relative to the vehicle.

16. A sensor assembly for measuring characteristics of motor oil in a vehicle, the sensor assembly comprising:

a housing adapted to be mechanically coupled to a vehicle; and

5 at least one capacitive sensor mechanically coupled to said housing, said at least one capacitive sensor including a plurality of sensing electrodes, said at least one capacitive sensor being adapted to measure at least one characteristic of motor oil between at least two of said sensing electrodes, each
10 of said sensing electrodes being covered by a nonconductive coating.

17. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 16 wherein each of said nonconductive coatings comprises a silicone coating.

18. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 16 wherein said at least one capacitive sensor comprises an oil level sensor.

19. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 16 wherein said at least one capacitive sensor comprises an oil deterioration sensor.

20. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 16 further comprising:

a tilt sensor mechanically coupled to said housing, said tilt sensor providing an output signal indicative of an

orientation of said tilt sensor relative to a vector representing forces applied to said tilt sensor.

AMENDED CLAIMS

[received by the International Bureau on 16 August 1999 (16.08.99);
original claim 16 amended; remaining claims unchanged (2 pages)]

coupled to said housing in a substantially fixed orientation relative to the vehicle.

16. A sensor assembly for measuring characteristics of motor oil in a vehicle, the sensor assembly comprising:

a housing adapted to be mechanically coupled to a vehicle; and

5 at least one capacitive sensor mechanically coupled to said housing, said at least one capacitive sensor including a plurality of sensing electrodes, said at least one capacitive sensor being adapted to measure at least one characteristic of motor oil between at least two of said sensing electrodes, each
10 of said sensing electrodes being covered by a nonconductive coating of silicone material;

whereby the soot build-up which occurs on capacitive sensor employed to sense the oil in certain types of internal combustion engines is substantially reduced or eliminated.

17. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 16 wherein each of said nonconductive coatings comprises a silicone coating.

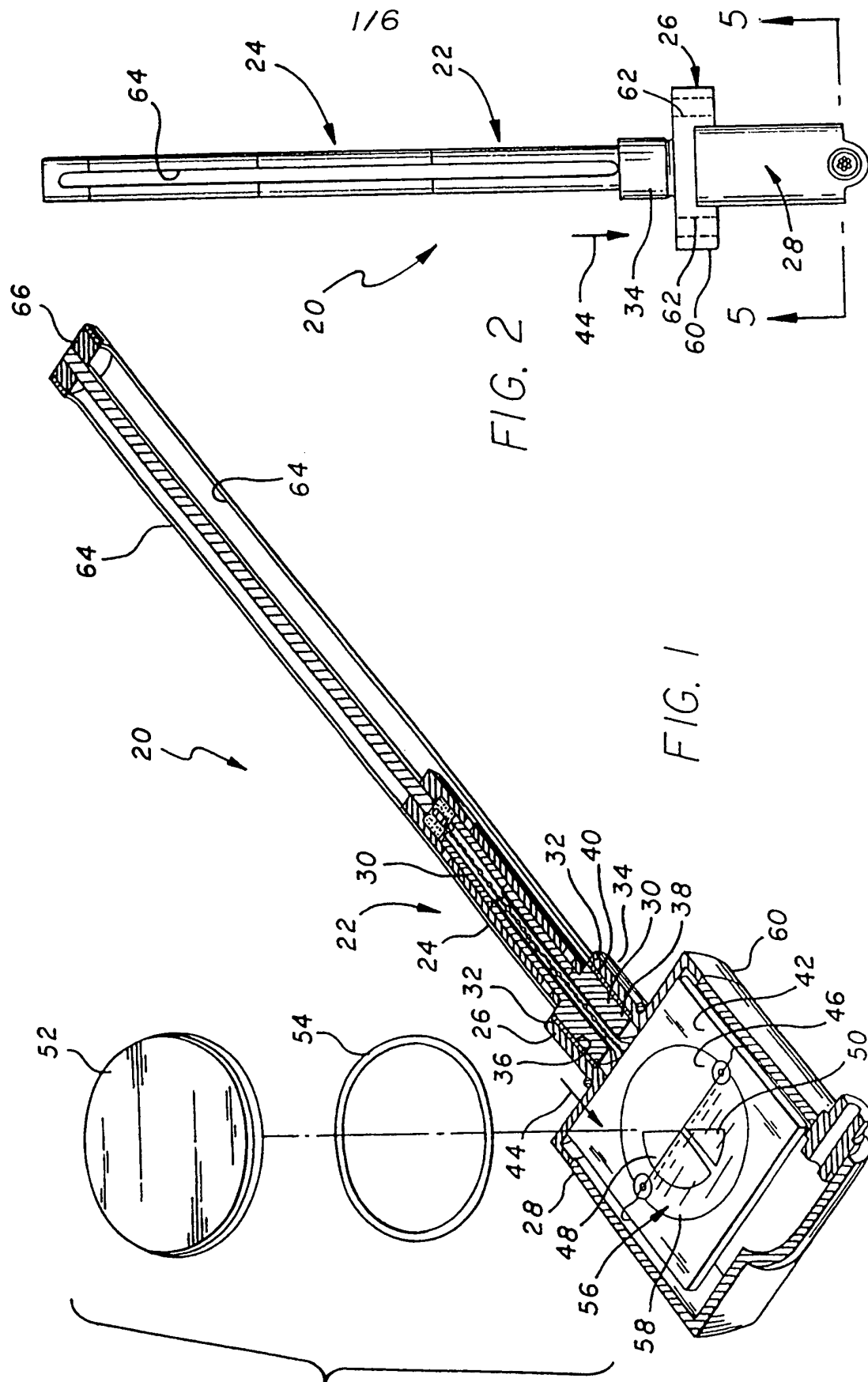
18. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 16 wherein said at least one capacitive sensor comprises an oil level sensor.

19. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 16 wherein said at least one capacitive sensor comprises an oil deterioration sensor.

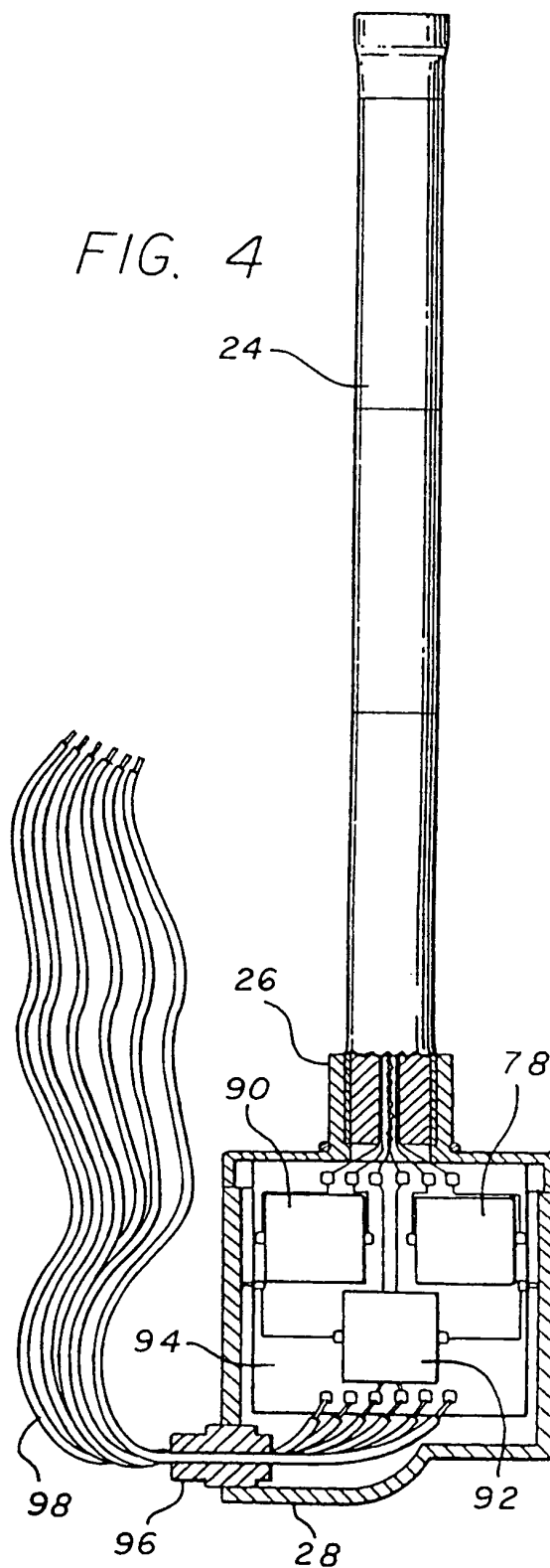
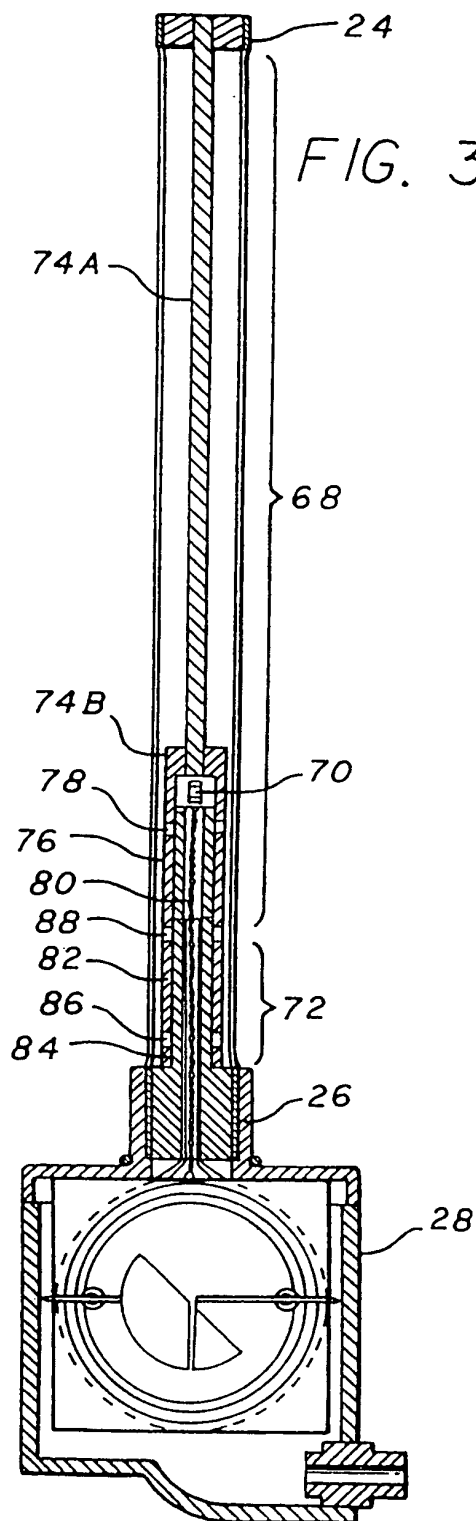
20. The sensor assembly for measuring characteristics of motor oil in a vehicle of claim 16 further comprising:

a tilt sensor mechanically coupled to said housing, said tilt sensor providing an output signal indicative of an

orientation of said tilt sensor relative to a vector representing forces applied to said tilt sensor.



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FIG. 5

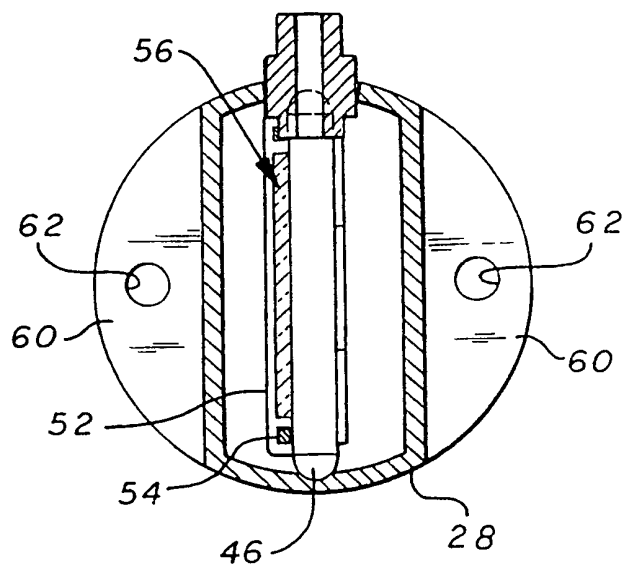
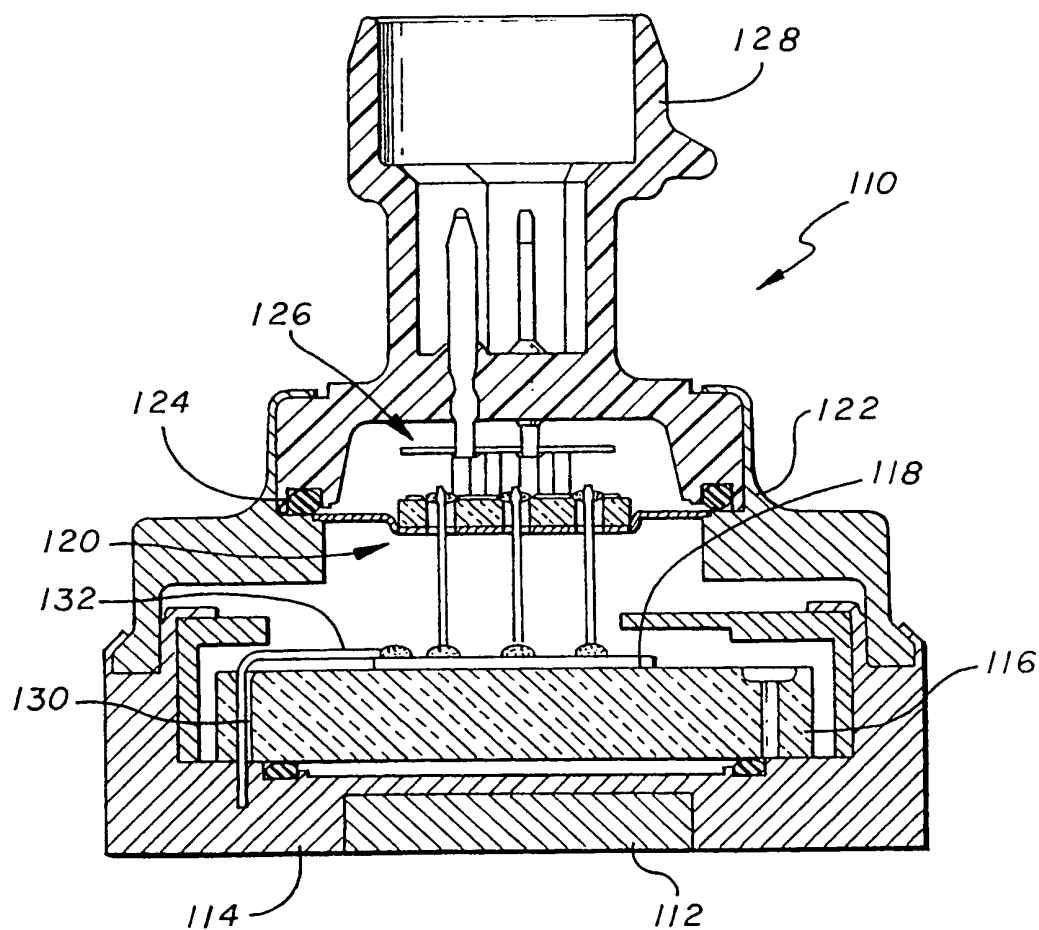


FIG. 10



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FIG. 6

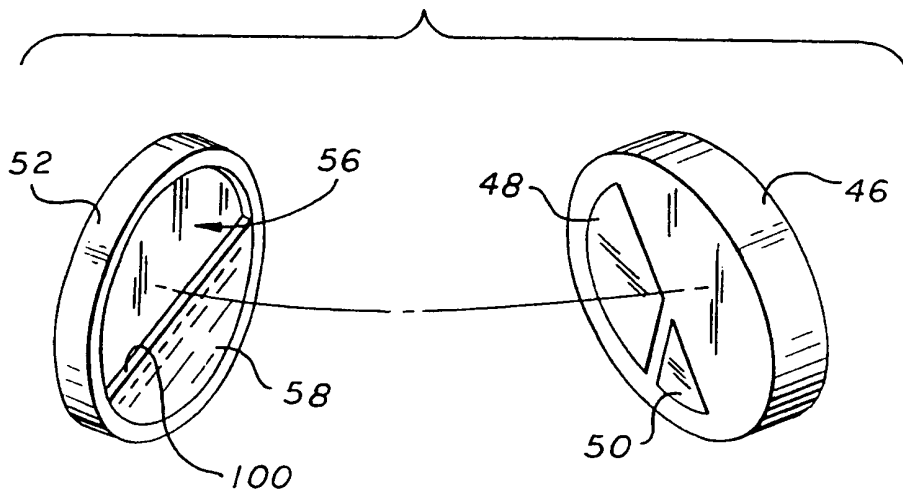


FIG. 7

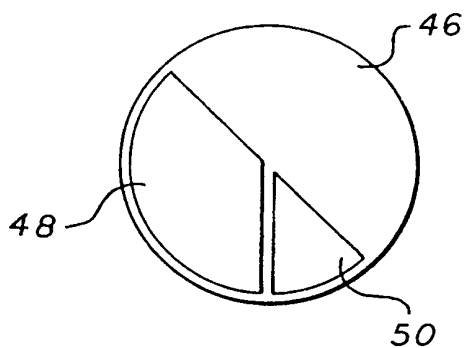


FIG. 8A

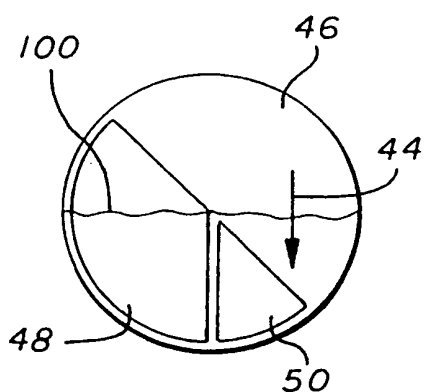
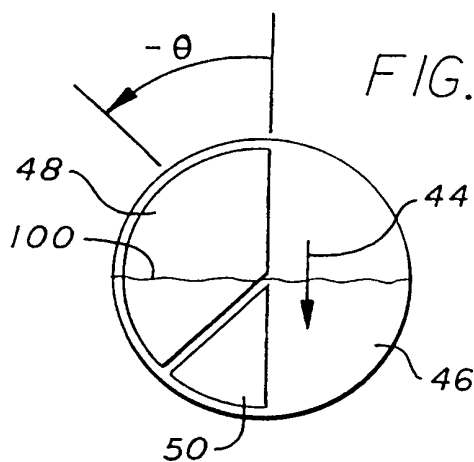


FIG. 8B

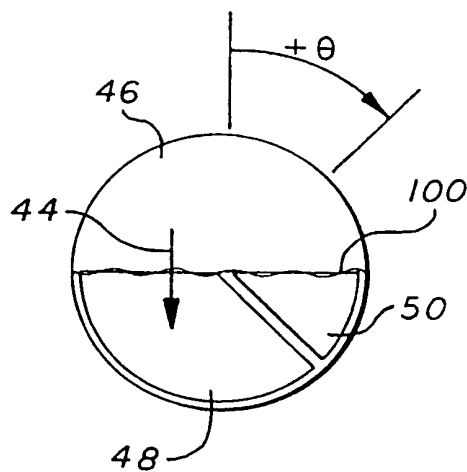


FIG. 8C

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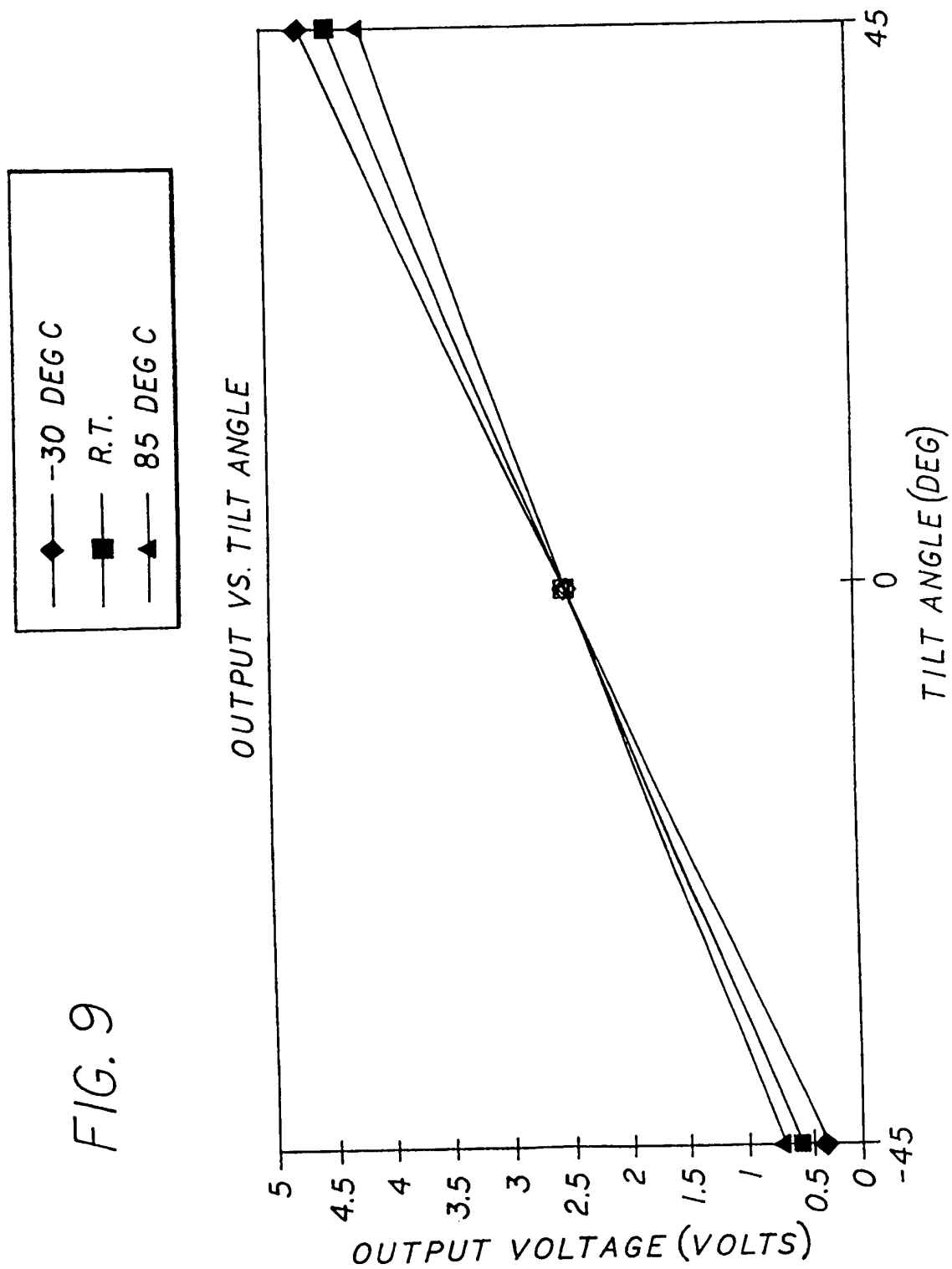
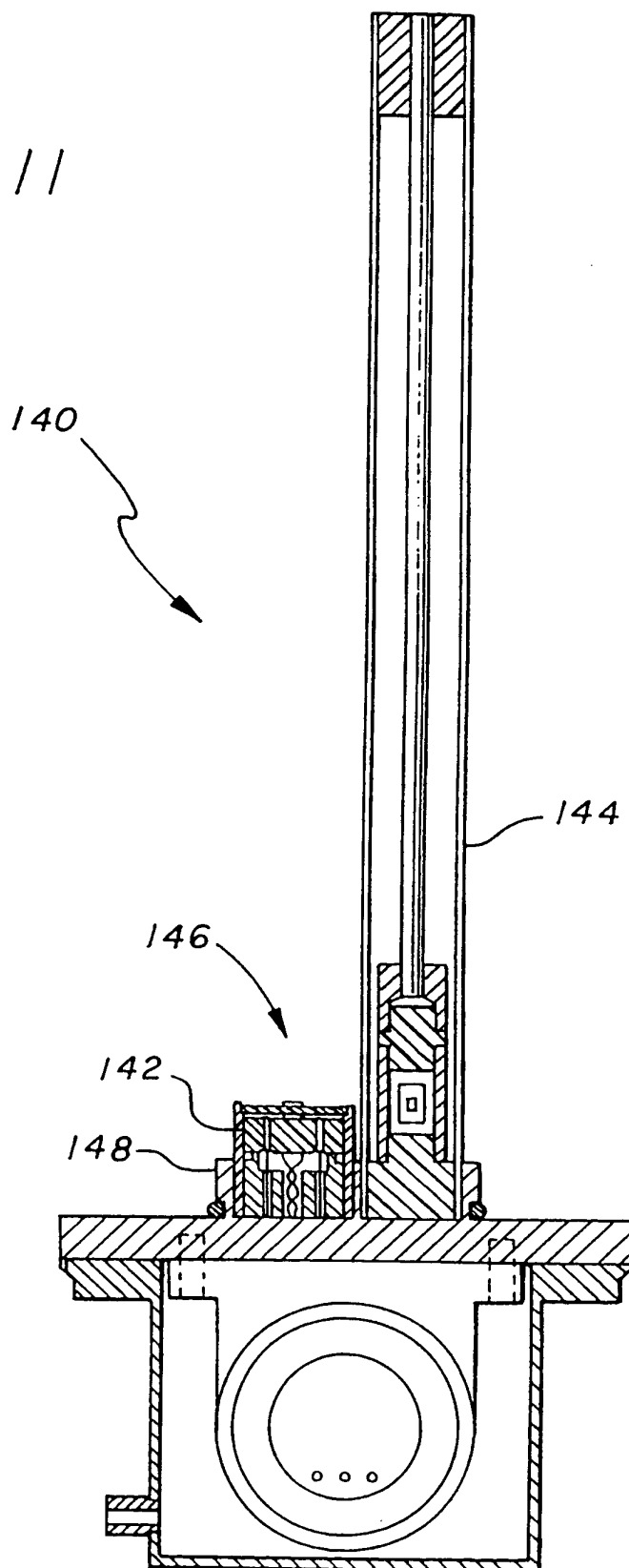


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/24331

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B60Q 1/00

US CL :Please See Extra Sheet.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS and DERWIN CDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,882,967 A [GULLA et al.] 13 May 1975, see Col.1, Lines 30-34, Col.4, Lines 50-57 and Figure.	9-10, 14-15, 16-18,20
Y	US 4,706,193 A [IMAJOE et al.] 10 November 1987, see Col.3, lines 23-24.	9-10, 14-15, 16-18,20
A,P	US 4,675,662 A [KONDO et al.] 23 June 1987, see Abstract and Figs.1-3.	1-20
A,P	US 4,782,698 A [WILSON] 08 November 1988, Abstract and Figs.1-2.	1-20
A,P	US 4,989,560 A [RASDAL et al.] 05 February 1991, Abstract and Figs.1 and 4A.	1-20
A,P	US 5,159,313 A [KAWAI et al.] 27 October 1992, Abstract and Fig.1.	1-20

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
B earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

03 FEBRUARY 1999

Date of mailing of the international search report

15 JUN 1999

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Joni Hill

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/24331

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A,P	US 5,382,942 A [RAFFA et al.] 17 January 1995, Abstract and Fig.1.	1-20

Form PCT/ISA/210 (continuation of second sheet)(July 1992)★

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/24331

A. CLASSIFICATION OF SUBJECT MATTER:

US CL :

340/438, 440, 441, 450, 450.3, 631, 691.1, 693.5;
73/295, 304C, 304R, 664;
123/196R, 196S

B. FIELDS SEARCHED

Minimum documentation searched

Classification System: U.S.

340/438, 440, 441, 450, 450.3, 631, 691.1, 693.5;
73/295, 304C, 304R, 664;
123/196R, 196S

